Removing Garlic Contamination From Harvested Wheat

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ABSTRACT

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Small grains, particularly Soft Red Winter wheat, often become contaminated with garlic, resulting in substantial discounts for the farmer and severe milling problems.

The best control is on the farm through good cultural practices, including spraying with herbicides when necessary. If good farming practices fail to give effective control, the grain should be cleaned, on the farm, *before* marketing. Simulation experiments indicated that a combine with proper attachments, after careful adjustment, can be used to remove garlic from harvested wheat. The material removed can be fed to livestock.

Conventional and experimental seed-cleaning devices are discussed. The most efficient method for removing garlic from wheat combines use of cleaning screens, squeeze rolls, and pneumatic separation.

Key Words: garlic, wheat, milling, grain-cleaning equipment, seed separators, weed seed.

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PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

Metric System Conversion Factors

Millimeter (mm) = 0.03937 inch
Centimeter (cm) = 0.3937 inch
Meter (m) = 39.37 inch or 3.2808 feet
Grams (g) = 0.035 ounce
Kilograms (kg) = 2.2 pounds
°C = (°F − 32) × 5/9

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Removing Garlic Contamination From Harvested Wheat

B. S. Miller, Y. Pomeranz, H. H. Converse,[1] and N. R. Brandenburg[2]

INTRODUCTION

Wild garlic (*Allium vineale* L.), a weed common to small grain fields in the Eastern United States, is sometimes confused with wild onion (*Allium canadense* L.), a closely related weed. Wild garlic has a cylindrical leaf with a cluster of hard and soft shell bulbs at the base of each plant; wild onion has a flat, solid leaf with only one bulb at the base. Knake and McGlamery (*7*)[3] and Peters and Stritzke (*11*) provide excellent illustrations of the garlic plant, bulbs, and bulblets (the source of grain contamination and also the cause of acute contamination in 1974). Håkansson (*5*) has written a comprehensive publication dealing with *Allium vineale* L. as a weed.

The aerial bulblets of the garlic plant are produced on a flowering stem. A simple cluster may contain as many as 300 bulblets, ranging from slightly smaller to larger than normal wheat kernels. When freshly harvested, they range in moisture from 40 to 50 percent. As they lose moisture, they shrink to approximately 40 percent of their original size. When harvested with wheat, barley, oats, or rye, the bulblets are difficult to separate from those grains.

In this publication the methods used to remove garlic from harvested wheat are summarized.

Extent of Problem

Wild garlic is a problem in Great Britain, Sweden, and the United States. It is particularly a problem in Soft Red Winter wheat in the United States, where it is generally present in Southern Illinois, Indiana, Ohio, Kentucky, Tennessee, Georgia, Missouri, North Carolina, South Carolina, Maryland, Oklahoma, and Virginia (*3*).

Wild garlic is not troublesome as a contaminant of cereal crops in Canada, Austria, West Germany, Hungary, Ireland, Norway, Turkey, Switzerland, East Germany, Argentina, Yugoslavia, The Netherlands, and Czechoslovakia. It grows to some extent in Tasmania and South Australia but not in New South Wales.

Economic Significance

Stored wheat with fewer than two green garlic bulblets, or an equivalent quantity of dry or partly dry bulblets in a kilogram, is classified as garlic-free; that with two to six green garlic bulblets, or an equivalent quantity of dry or partly dry bulblets in a kilogram, is classified as light-garlicky; and that with more than six green bulblets, or an equivalent quantity of dry or partly dry bulblets in a kilogram, is considered garlicky. (Three dry bulblets are equal to one green bulblet.)

Garlic-contaminated wheat sells at a significant discount because it is difficult to mill and because the resulting flour may have a garlic odor caused by allyl sulfide in the crushed bulblets. The greater the number of garlic bulblets, the higher will be the discount per bushel of wheat. Prior to 1974, price discounts for Soft Red Winter wheat contaminated with garlic ranged from 6 to 12 cents per bushel. But in 1974, because of an abundance of garlic-free wheat as well as wheat heavily contaminated with garlic in certain areas, price discounts commonly ranged up to $2.00 per bushel. As much as 35 percent of the 1974 soft wheat crop was graded garlicky. Mills and elevators refused to buy garlicky wheat at any price in some areas where garlic counts ran as high as 600 bulblets per kilogram sample and where counts of 200 to 300 were commonplace (*3*).

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[3] Italic numbers in parentheses refer to Literature Cited p. 11.

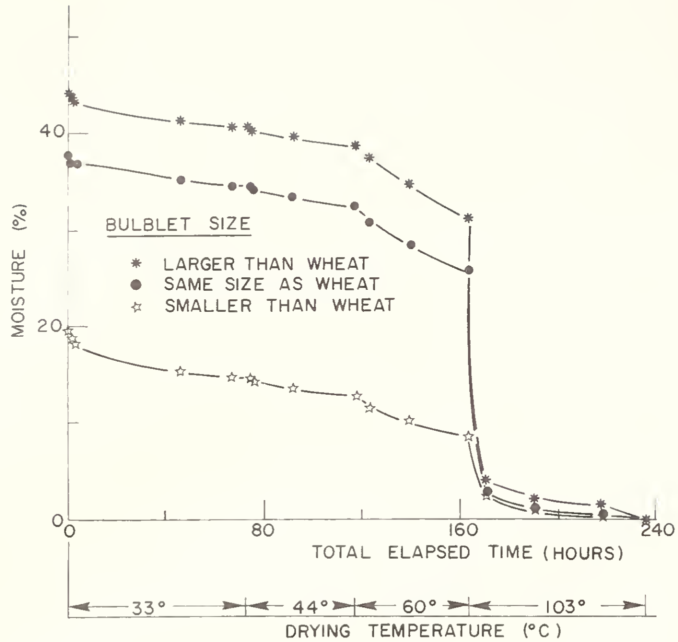

FIGURE 1.—Temperature-time-moisture relation for garlic bulblets of different sizes removed from wheat (lot 1).

Milling Problems

The impurities of wheat and the five principal methods used to remove them have been described by Smith (*12*). In 1970 a patent (*4*) was issued describing an apparatus and method for doffing weed seed (including garlic). The apparatus cleans the surface of a pair of crushing rollers during the process of milling grain contaminated with weed seed.

Millers dislike garlicky wheat because the bulblets adhere to the corrugated rolls. Also, the gummy material from crushed bulblets forms a hard coating around the rolls, which contributes to decreased flour yield, decreased efficiency of the milling process, and, in some cases, low-quality flour with high ash. The only way to restore milling efficiency is to clean the rolls.

Sopher (*13*) quoted a leading mill builder as saying:

> In some cases the rolls are washed after shutting down, but where water is applied while the mill is in operation, the water is put on a very small section of the roll, which allows a dough ball to form. As this dries out, the centrifugal force of the roll throws off big chunks, or sections. This is repeated down through the length of the roll and it cleans the corrugations very readily. It is desirable with this system, to put a scalping shoe below each pair of rolls while water is applied to remove the dough balls or chunks, thus preventing them from going down into the system and causing chokeups in the sifters.

Millers contend that the costs of cleaning the grain and washing the rolls make milling wheat with more than 30 to 50 bulblets per kilogram uneconomical (*3*).

Control on the Farm

The best way to eliminate wild garlic is to plant wheat only on land that is garlic-free. In areas where garlic is prevalent, the problem can be reduced by raising such cultivated crops as corn and soybeans for several years to prevent the formation of aerial bulblets. Because dormant, hard-shell garlic bulbs can remain viable in soil for 5 to 6 years, a program to eradicate the weed should continue for at least 6 years.

To inhibit formation of aerial bulblets on garlic growing in wheat fields, 2,4-D should be applied when the wheat plants are 10 to 15 cm high, after they have tillered and before nodes are visible. Spraying kills one-third to one-half of the garlic plants (*2*).

Feeding Experiments

Feeding experiments at the University of Illinois Agricultural Experiment Station (*14*) indicate that wheat with a high garlic content used in feed rations produces no harmful effects on beef and dairy cattle, swine, sheep, or poultry. Some chickens, however, refused to eat garlicky wheat. Wheat fed to beef cattle, sheep, and swine averaged 274 bulblets per kilogram; that fed to dairy cows contained 95 bulblets per kilogram, and that fed to poultry averaged 312 bulblets per kilogram.

Contrary to popular opinion, milk and milk products from cows fed garlicky rations did not have an onion or garlicky odor (*14*). Morrison (*10*), however, discussing flavors and odors in milk, states "the most marked flavor is produced by garlic, onions. . . . An off-flavor caused by feed can be prevented or lessened by feeding the particular feed only immediately after milking." The time and amount of feeding of garlic-contaminated wheat may explain the difference in results (*14, 10*).

TABLE 1.—*Composition of garlicky wheat*

Lot No.	Source of wheat	Garlic content: Percent by weight	Garlic content: Bulblets per kilogram wheat	Moisture content percent: Wheat	Moisture content percent: Garlic bulblets[1]: Soft bulblets	Garlic bulblets[1]: Intermediate bulblets	Garlic bulblets[1]: Hard, dry pieces
2	Missouri	0.91	625	10.5	Ave. ←	51.5	→ Ave.
3	Indiana	1.84	1,120	9.75	59.5	39.5	12.1
4	Ohio	.16	155	9.8	48.8	28.2	8.8

[1] Soft bulblets were moist and had intact hulls; intermediate bulblets had cracked hulls; dry, hard bulblets had no hulls.

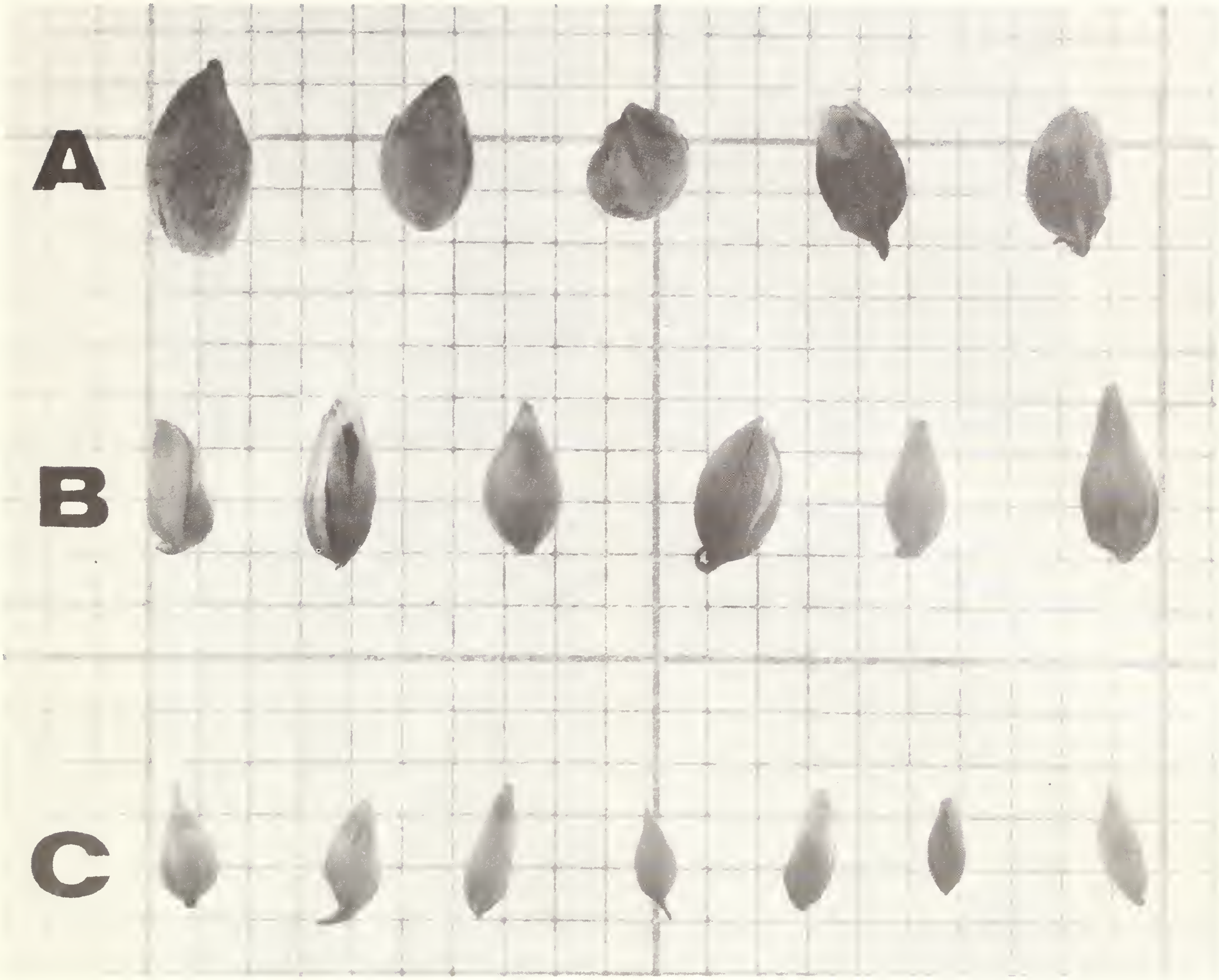

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FIGURE 2.—Representative samples of garlic bulblets taken from wheat (lot 1) and shown on a background of 2.54-mm graph paper: Row A—Samples will not pass through a screen that passes wheat. Row B—Samples will pass a screen that passes wheat. Row C—Samples will pass a weed screen that will not pass sound wheat.

MATERIALS

Several lots of garlicky wheat were used. Lot 1 consisted of approximately 45.4 kilograms of garlicky wheat (13 percent moisture) from Evansville, Ind.; it contained 352 green (with husks) and 424 dry (without husks) garlic bulblets per kilogram. Because three dry bulblets are considered to be equal to one green bulblet, the garlic count of the wheat for grading purposes was 500 per kilogram. The original lot was divided into kilogram samples for testing. Lots 2, 3, and 4 each consisted of 4.5 kilograms of garlicky wheat. Composition of the lots is shown in table 1.

RESULTS AND DISCUSSION

Moisture Content of Garlic

Moisture content of green garlic bulblets in lot 1 was 44 percent and of dry garlic bulblets 19 percent. Drying tests conducted at different temperatures revealed that the green bulblets dried slowly. At an air-drying temperature of 60.0°C, in 1 hour the moisture content of green garlic bulblets remained nearly constant while the wheat dried 2 percent. With an air-drying temperature of 32.2°C, the green garlic bulblets dried in 5½ hours to a moisture content of 33 percent. More detailed evidence that garlic dried slowly is provided in figure 1.

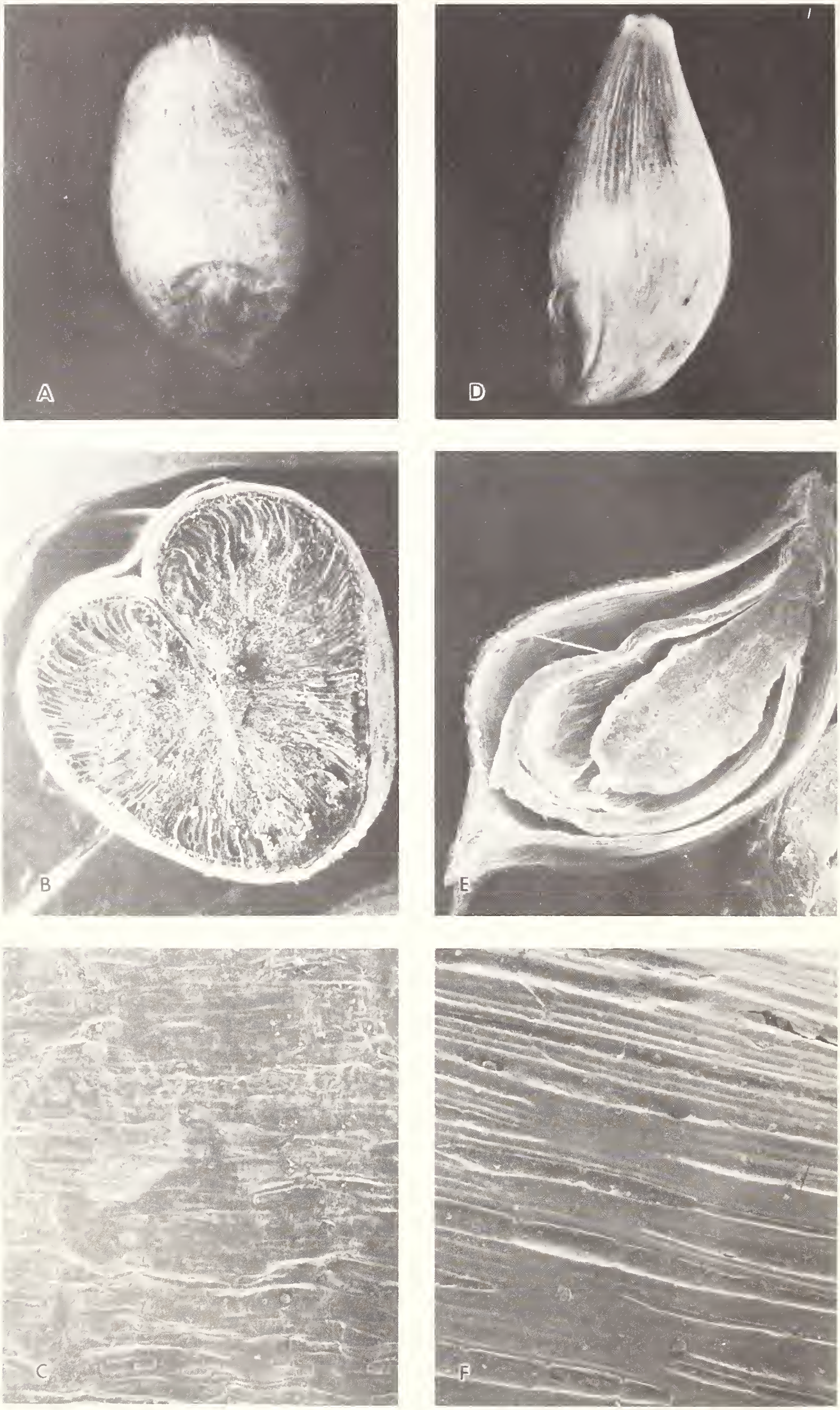

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FIGURE 3.—Light microphotographs of A—whole wheat kernel (10×); D—whole garlic bulblet (10×). Scanning electron-microphotographs of B—cross section through a whole wheat kernel (20×); E—transverse section through a whole garlic bulblet (16×); C—surface of a wheat kernel (145×); and F—surface of a garlic bulblet (145×).

Garlic bulblets of different sizes were hand picked from wheat fractions (coarse dockage, dockage-free, and fine dockage) separated by a Carter dockage tester[4] (fig. 2). The size and shape of a wheat kernel and a garlic bulblet are compared in figure 3.

Lockwood (8) recommended that garlicky wheat should remain in storage for some time after drying to about 10 percent moisture for optimum separation of garlic by aspiration (fig. 3). Green garlic bulblets contain much free space within the bulblets in contrast to dried bulblets.

Bulk Density of Garlic Bulblets

Small, dry garlic bulblets that passed through a 3.57 mm triangular (No. 8) sieve were used for bulk density evaluation. This material at 19 percent moisture had bulk density equivalent to 0.69 that of clean wheat and 0.80 that of cracked and shriveled wheat. Larger garlic bulblets at 40 percent moisture had a bulk density equivalent to 0.61 that of clean wheat.

Removing Garlic by Carter Dockage Tester

The garlic count of lot 1 was reduced from 500 to 300 in a sample run through a Carter dockage tester equipped with a No. 1 riddle, a No. 8 sieve with triangular holes 3.57 mm on a side, and a 1.98 mm round-hole screen. The green garlic count was reduced from 352 to 286; the dry garlic count from 424 to 42. Percentages of wheat in various separations are shown in table 2. Practically all the garlic was found in fractions A, B, and D. By weight, 20 percent of the garlic was found in fraction A, 20 percent in fraction B, and 60 percent in the cleaned wheat (fraction D).

TABLE 2.—*Garlicky wheat separated on a Carter dockage tester*

Fraction	Separation	
		Percent
A..	Large material over No. 1 riddle	0.4–0.5
B..	Shrunken, broken kernels; weed seeds (through a No. 8 sieve)	1.8–1.9
C..	Through 1.98 mm round-hole sieve and air separation	0.2–0.3
D..	Remaining cleaned wheat	97.3–97.4

Methods for Removing Garlic Evaluated

Many methods for removing garlic from wheat were evaluated in 1974 at two ARS locations: U.S. Grain Marketing Research Center, Manhattan, Kans.; and Seed Harvesting and Processing Equipment Project, Corvallis, Oreg.

Four methods for removing garlic from wheat were evaluated at Manhattan, Kans.: (1) separation by bouncing, based on the difference in resiliency of wheat and garlic; (2) separation using a grain spectrometer (6), based on differences in aerodynamic drag; (3) separation by flotation, based on buoyancy differences between wheat and garlic; and (4) separation by aspiration, based on differences in aerodynamic drag.

Bouncing

Dropping the wheat from 4.6 meters above an inclined surface and trapping the material that bounced on shelves (fig. 4) showed little promise as a method for removing garlic. Wheat on the shelves contained 170 garlic bulblets per kilogram.

Grain spectrometer

The device developed by Katz, Farrell, and Milner (6) for segregating wheat according to test weight was not promising. Only 8 of the 1,000 grams of wheat separated was totally free of garlic.

Flotation

When uncleaned wheat was immersed in water, only those bulblets with husks floated (fig. 5). The seeds without husks remained immersed, took up water

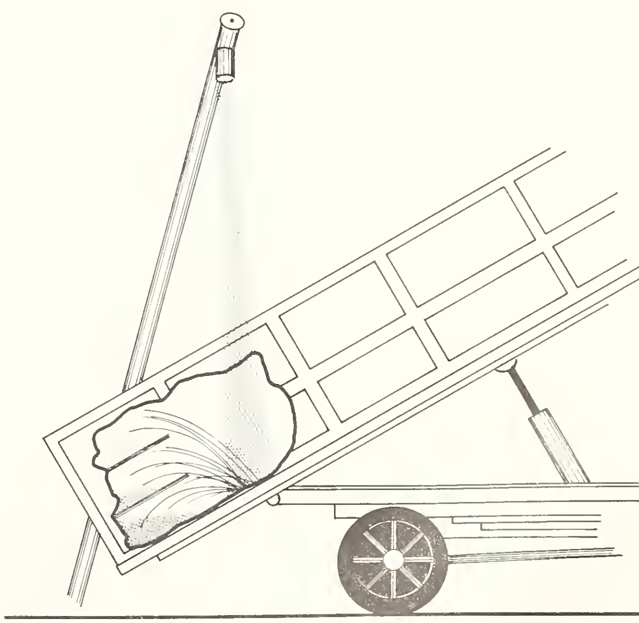

FIGURE 4.—Equipment for separating garlic from wheat by bouncing.

[4] Trade names are used solely to provide specific information. Mention of them does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture nor an endorsement by the Department over other firms not mentioned.

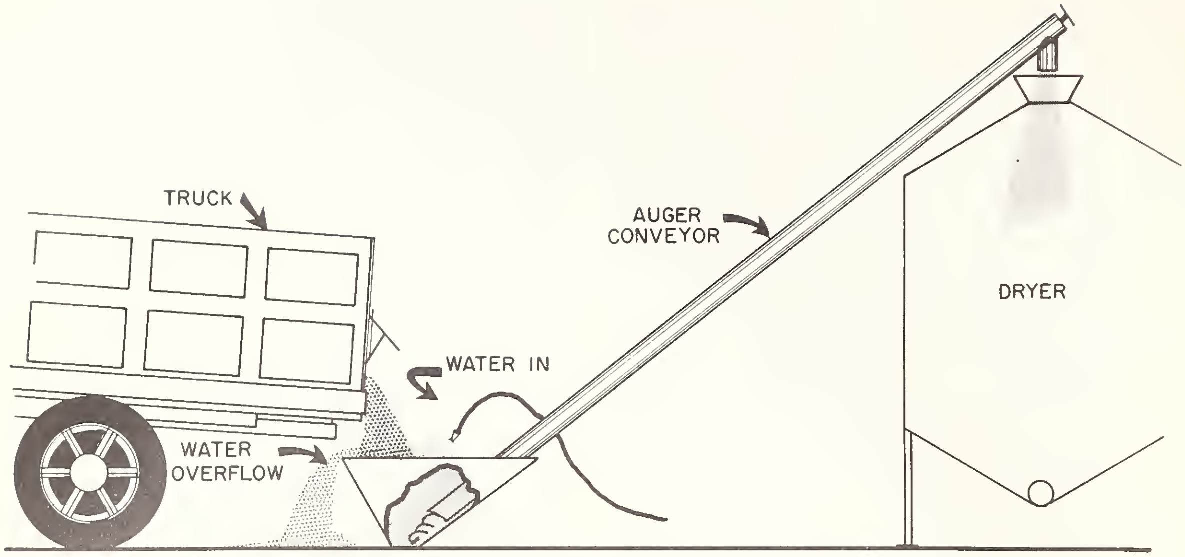

FIGURE 5.—Equipment for separating garlic from wheat by flotation.

rapidly, swelled, and became turgid. Most of the green garlic bulblets remaining after the wheat was screened could be removed by flotation. After the wheat was immersed for 5 minutes in water, the moisture content increased 24 to 28 percent. A sample immersed for 2 minutes and then surface-dried with toweling had a moisture content of 19 percent, an increase of only 6 percent, indicating that most of the water was on the surface of the grain. That was confirmed when moisture was rapidly removed by forcing room air through the sample. Thus, by combining screening and flotation, almost all garlic was removed. If the wheat had been dried immediately, the moisture could have been removed rapidly with natural or slightly heated air.

Loewer, White, and Ross (*9*), who evaluated the flotation process for separating garlic from wheat, concluded that a high degree of separation could be achieved by that process. They also concluded that additional research is necessary to quantify the influence of several factors, including wheat and garlic moisture, to develop machinery to carry out the flotation process.

Aspiration

Several samples of wheat (approximately 120 grams each) were dried at 121.1°C and removed from the oven at different time intervals. Garlic was removed by aspiration (table 3). Even though the garlic count could be reduced from 300 to as few as 11½ bulblets per kilogram, enough garlic remained to classify the wheat as garlicky. From 9 to 16 percent of the wheat was carried over with garlic during aspiration; however, much of this wheat consisted of broken and shrunken kernels that had not been removed by screening.

Procedures Suitable for Farm Use

These results indicate that the amount of garlic in wheat can be materially reduced by simple procedures

TABLE 3.—*Garlic separated by aspiration after drying (115 to 120 gram samples)*

Drying time[1]	Moisture content	Garlic bulblets removed by aspiration	Bulblets remaining: Green	Dry	Equivalent per kilogram wheat
Minutes	*Percent*				
5	11.2	43	6	1	52.7
10	9.9	38	1	1	11.5
15	9.1	36	2	1	20.4
20	8.1	37	2	3	26.0
30	7.2	28	1	2	14.5
40	6.3	35	1	3	17.3

[1] Forced draft oven at 121.1°C.

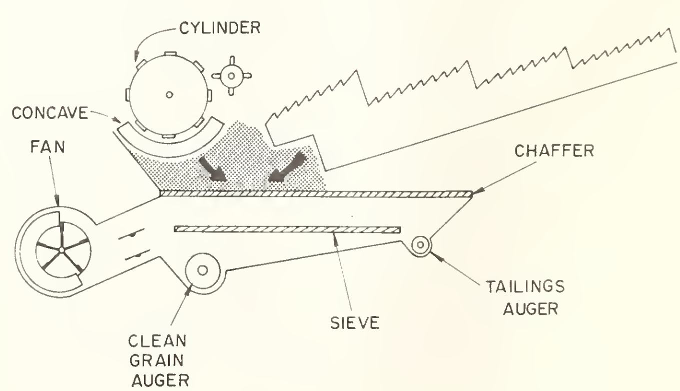

FIGURE 6.—Combine components—cylinder, concave, and cleaning shoe (chaffer, sieve, and cleaning fan)—to be adjusted carefully for optimum removal of garlic from wheat.

on the farm (*3*). The most promising is rethreshing wheat with a combine (fig. 6). In operation, the grain-cleaning shoe of a combine combines screening and aspirating as air passes through and over the sieve. The sieve and amount of air can be adjusted properly so that large bulblets will be carried over the vibrating chaffer, most of the medium bulblets will be separated by the cleaning sieve, and heavier wheat kernels will pass through the cleaning sieve.

To solve the remaining problem—removing dry garlic bulblets smaller than wheat—some combines are equipped with a weed and dirt screen in the bottom of the cleaning shoe through which fine material passes. Others have a perforated pan available for the bottom of the grain auger or a perforated spout that can be attached to the clean-grain cross-conveyor and elevator or both. Some combines have a special cleaning device that can be installed ahead of the point at which the grain goes into the holding bin of the combine. If any of these options are available, they will enable the small, dry garlic seed (along with shrunken and broken kernels of wheat) to be separated from the wheat.

According to simulated tests at the U.S. Grain Marketing Research Center, a separation efficiency of at least 90 percent is possible with a single pass through the combine; wheat heavily contaminated with garlic could be passed twice through the combine. Most combines, including self-propelled machines, can be adapted to operate in a stationary position at a level cleaning site. Then the wheat may be auger-conveyed from the storage bin to a feed spout above the combine's tailings entrance near the threshing cylinder. A suitable Y-type feeding spout would have to be made to attach to or replace the existing tailings return entrance to allow the garlicky wheat to feed in by gravity along with the tailings-return material.

Suitable leveling or positioning of the combine is required for optimum operation of the pneumatic clean-

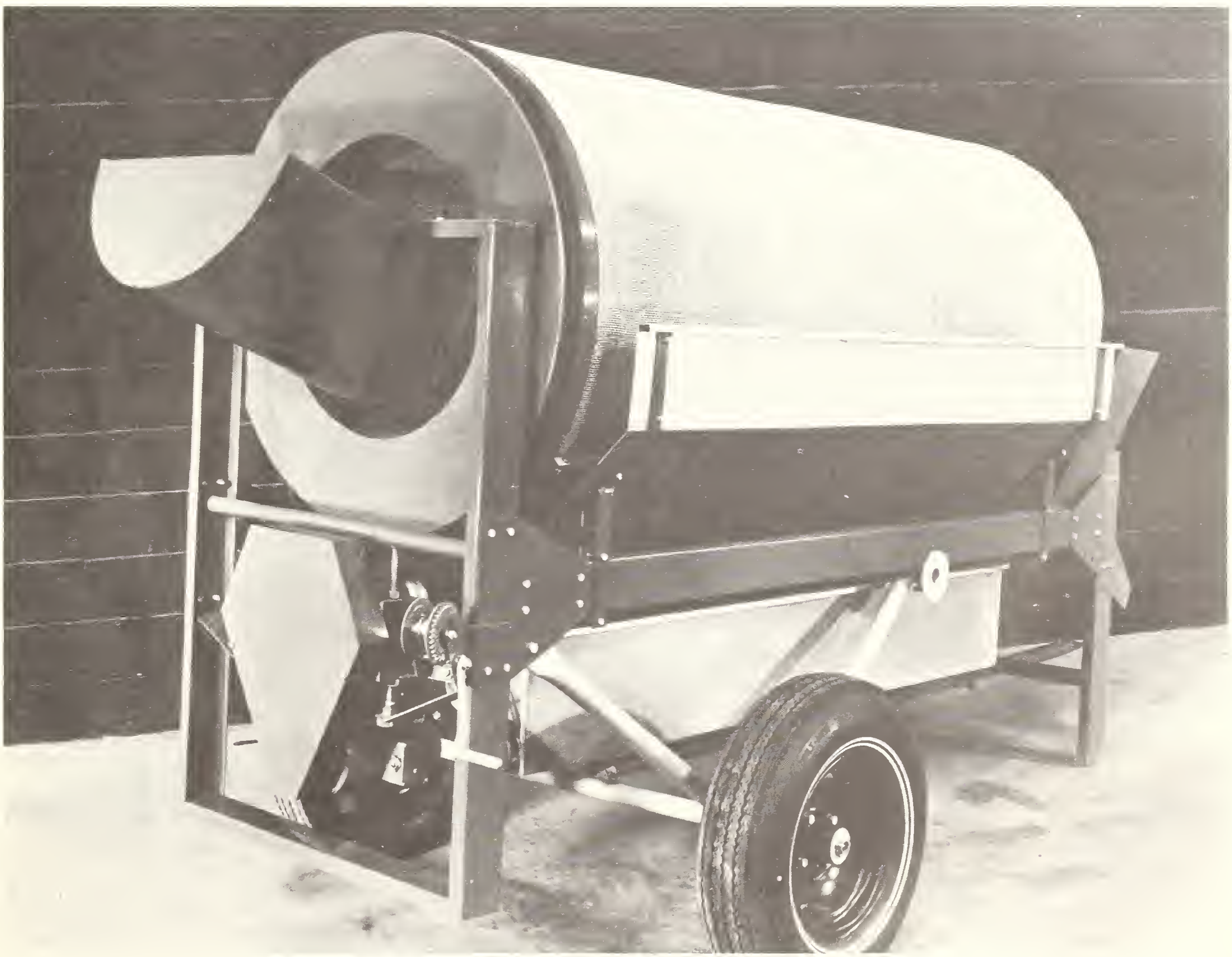

FIGURE 7.—A revolving screen-type cleaner. PN-5805

ing mechanism and cleaning shoe with chaffer, intermediate, and grain sieves. Cleaning fan speed should be increased or adjusted to obtain maximum aerodynamic action.

Such components as the combine's header and straw spreader need not run. The combine cylinder speed must be adequate to distribute the wheat across the width of the straw raddle and cleaning shoe but slow enough to minimize damaging whole kernels.

FOR SAFETY, ALL CAUTIONS AND WARNINGS ON OPERATING THE COMBINE MUST BE COMPLIED WITH IN FULL. Any operator having questions on operating a particular combine should discuss them with the local implement dealer or manufacturer's representative.

If weed or dirt screens are not available for the combine, a separate cleaner may be used to remove the small, dry garlic bulblets. A simple, revolving, screen-type cleaner (fig. 7), normally used to remove fine material from corn, is inexpensive. When a screen of suitable size is used, it would adequately remove small, dry garlic bulblets. An 8 × 8-mesh, woven-wire cloth of 0.9 mm diameter (22 gage) wire, with an opening of 2.46 mm, is recommended. Such a screen should adequately remove the dry garlic bulblets as efficiently as a sieve with triangular holes 3.57 mm on a side.

If a farmer has a dryer but not a combine, garlic can be separated from wheat by flotation (fig. 5). However, a separate cleaner (fig. 7) would be necessary to remove the small, dry garlic bulblets. Garlic bulblets with husks could be floated off almost as efficiently as with the air-separating device. During good weather, the moisture picked up by the wheat from immersion in water could probably be removed safely with forced (unheated) air without adding heat to the dryer.

Use of Conventional and Experimental Cleaning Machines

Brandenburg (*1*) and staff members of the ARS Seed Harvesting and Processing Equipment Project, Corvallis, Oreg., conducted many separating trials with conventional and experimental seed cleaning equipment. They worked with three different lots of garlicky wheat (table 1) and reported results from various trial separations on the basis of wheat yield and remaining garlic bulblets per kilogram. Exploratory work on different machines was carried out with the sample from Missouri (lot 2). Machines that did not appear promising were the vibrator separator (sandpaper deck), inclined draper, electrostatic separator, and friction separator. Best results were obtained with the screen, pneumatic, or gravity separators, belt thresher; and squeeze rolls in various combinations (table 4). Based on garlic count, wheat yield, and machine type, test 17 was the best trial separation.

TABLE 4.—*Selected trials—removing garlic bulblets from wheat (lot 2)*

Test No.	Garlic bulblets per kilogram wheat	Wheat yield (percent by weight)	Machines[1]
5......	0	66.6	Screens, gravity separator.
8......	0	72.5	Screens, gravity separator, belt thresher, pneumatic separator.
15......	0	70.2	Screens, rolls, pneumatic separator.
6......	1⅓	74.9	Screens, gravity separator.
7......	2½	79.1	Screens, gravity separator, belt thresher, pneumatic separator.
16......	3	75.8	Screens, rolls, pneumatic separator.
17......	3	80.6	Screens, rolls, pneumatic separator.

[1] Machines used in the sequence shown. Tests involving the same machine sequences employed different conditions of airflow, divider settings, or fractions accepted.

The operation sequence for test 17 was screening, rolling, and pneumatic separation. Screening was accomplished using round-hole (3.77 mm) top and round-hole (2.78 mm) bottom screens agitated vertically at high frequency. Material held on the top screen and dropped by the bottom screen was discarded. Material dropped by the top screen and held on the bottom screen was passed through the squeeze rolls, which crushed the

TABLE 5.—*Separating garlicky wheat (lot 2) using test procedure 17 (screens, rolls, pneumatic separator)*

Fraction	Percent of total lot (by weight)	Description
Held on 3.77 mm round-hole screen	2.0	Large garlic bulblets, large wheat kernels, large stems.
Through 2.78 mm round-hole screen	4.9	Small garlic bulblets, small wheat kernels, grass seed, fine inert material.
Through 3.77 mm round-hole screen, held on 2.78 mm round-hole screen, lifted in pneumatic separator	12.6	Crushed garlic bulblets, crushed wheat kernels, whole wheat kernels.
Through 3.77 mm round-hole screen, held on 2.78 mm round-hole screen, dropped in pneumatic separator.	80.6	Acceptable wheat containing three garlic bulblets per kilogram.

TABLE 6.—*Relation between garlic count and wheat yield in pneumatic separation*[1] *(lot 2)*

Test No.	Garlic bulblets per kilogram wheat	Wheat yield (percent by weight)	Air velocity (m/min)
15	0	70.2	419
16	3	75.8	389
17	3	80.6	366
18	11	83.6	347

[1] Complete processing sequence: screens, rolls, and pneumatic separator.

bulblets and made them easier to remove pneumatically. The squeeze rolls consisted of a pair of rolls (one of hard wood and one of hard rubber, each 7 cm in diameter) spring-loaded to minimize wheat breakage at high feed rates. The rolled material then was passed through a pneumatic separator with a vertical air column 15 cm in diameter. Fractions resulting from this procedure (test 17) are described in table 5.

TABLE 7.—*Selected trials—removing garlic bulblets from wheat (lot 3)*

Test No.	Garlic bulblets per kilogram wheat	Wheat yield (percent by weight)	Machines[1]
14	0	83.5	Screens, rolls, pneumatic separator (roll assembly C, air setting B).
20	0	83.1	Screens, rolls, pneumatic separator (roll assembly C, air setting B).
6	3	74.3	Screens, rolls, pneumatic separator (roll assembly A, air setting A).
8	3	73.4	Screens, rolls, pneumatic separator (roll assembly B, air setting A).
2	3⅓	52.5	Screens, gravity separator.

[1] Screens:
3.97 mm round-hole top screen and 2.78 mm round-hole bottom screen.
Rolls:
Roll assembly A—one soft rubber roll; one medium-hard rubber roll; minimum spring compression.
Roll assembly B—one soft rubber roll; one medium-hard rubber roll; maximum spring compression.
Roll assembly C—one hardwood roll; one medium-hard rubber roll; minimum spring compression.
Hardwood roll—6.4 cm diameter; rubber rolls—7 cm diameter.
Pneumatic separator:
Verticle air column 15.2 cm diameter.
Air setting A—424 m/min air velocity.
Air setting B—393 m/min air velocity.

TABLE 8.—*Separating garlicky wheat (lot 3) using test procedure 14 (screens, rolls, pneumatic separator)*

Fraction	Percent of total lot (by weight)	Description
Held on 3.97 mm round-hole screen	1.6	Large garlic bulblets, large wheat kernels, large inert material.
Through 2.78 mm round-hole screen	2.7	Small garlic bulblets, small wheat kernels, grass seed, fine inert material.
Through 3.97 mm screen, held on 2.78 mm screen, lifted in pneumatic separator.	14.2	Crushed garlic bulblets, crushed wheat kernels, whole-wheat kernels, light inert material.
Through 3.97 mm screen, held on 2.78 mm screen, dropped in pneumatic separator.	81.5	Acceptable wheat with no garlic.

Results for any one machine sequence showed a direct relation between garlic count and wheat yield (lower garlic counts were associated with lower wheat yields) (table 6). The only change was air velocity in the pneumatic separator after screening and rolling. Air velocity is critical in obtaining maximum wheat yield with minimum garlic content.

TABLE 9.—*Selected results—removing garlic bulblets from wheat (lot 4)*

Test No.	Garlic bulblets per kilogram wheat	Wheat yield (percent by weight)	Machines[1]	Remarks
2	0	90.4	Screens pneumatic separator.	Air velocity—(389 m/min)
3	2⅓	93.1	Screens, pneumatic separator.	Air velocity—(366 m/min)
5	0	93.2	Pneumatic separator.	Air velocity—(389 m/min)
6	2	92.9	Pneumatic separator.	Verification of test 5.
8	0	89.0	Rolls, pneumatic separator.	Air velocity—(366 m/min)
9	12⅓	94.5	Rolls, pneumatic separator.	Air velocity—(343 m/min)
10	5	92.7	Rolls, pneumatic separator.	Air velocity—(347 m/min)
14	11⅓	94.1	Rolls, pneumatic separator.	Verification of test 9.

[1] Screens: 3.97 mm round-hole top screen and 2.78 mm round-hole bottom screen. Pneumatic separator: a vertical air column (152 mm diameter). Rolls: one hardwood roll (63.5 mm diameter) and one medium-hard rubber roll (69.9 mm diameter).

The sample from Indiana (lot 3) contained a high percentage of hard, dry bulblets not present in the sample from Missouri. Initially, separation procedures included those found promising for the Missouri samples. Later trials employed other machines to eliminate the dry, hard bulblets. Results from these machines, the bounce plate separator, slotted screens, velvet rolls, and inclined chute, were not promising. Good results were obtained using the machine sequences shown in table 7. Best results were obtained in test 14 using a combination of screens, squeeze rolls, and a pneumatic separator. The screens consisted of a round-hole (3.97 mm) top screen and a round-hole (2.78 mm) bottom screen agitated vertically at high frequency. Material held on the top screen and dropped by the bottom screen was discarded. Material dropped by the top screen but held on the bottom screen was passed through the squeeze rolls. The roll assembly consisted of a pair of spring-loaded rolls (6.4-cm diameter, hardwood; 7-cm diameter, medium-hard rubber). In the operating position, the hardwood roll deformed the rubber roll slightly. The rolls modified the aerodynamic properties of the bulblets so they could be more easily removed by pneumatic separation. An air setting of 393 meters per minute produced the best results in the pneumatic separator. Replicates of test 14 resulted in garlic bulblet counts of 0, 5½, and 5 per kilogram; and wheat yields of 83.1, 84.4, and 82.9 percent, respectively. The average of the four trial runs was two garlic bulblets per kilogram and a wheat yield of 83.5 percent. The resulting fractions from test 14 are described in table 8.

The lot of garlicky wheat from Ohio (lot 4) contained moist and dry bulblets. The moist bulblets had a high percentage of cracked hulls. Processing included the use of screens, pneumatic separator, and squeeze rolls in various combinations. The best tests are shown in table 9. With this lot, the use of squeeze rolls did not appear to improve results. Use of a pneumatic separator alone effectively separated garlic from the wheat (test 5, table 9).

RECOMMENDATIONS

1. Assure that wheat is garlic-free by controlling wild garlic on the farm with the following steps:
   a. Plant clean wheat seed in garlic-free fields;
   b. Plow and begin cultivation of row crops early to prevent formation of new aerial bulblets;
   c. Obtain a vigorous stand of wheat with adequate seeding and fertilizing;
   d. Apply herbicides to wheat in the spring; and
   e. Adjust combine to remove as much wild garlic as possible.
2. Clean the wheat *before* marketing if these steps have not been taken or if the results are not adequate.
3. Use a combine for the most convenient and economical method of removing garlic from harvested wheat. With proper attachments and careful adjustments, a combine will remove most of the garlic. The 10 percent wheat lost can be fed to livestock.
4. Modify or develop the cleaning equipment for flour mill use to provide an operating sequence of effective screening, followed by appropriate crushing and selective air separating. The required operating sequence may be achieved by using separate existing machines with modifications as needed. One machine—the conventional air-screen separator—can be adapted to meet all of these requirements to remove garlic bulblets adequately from wheat. Clod-crushing rolls are available as a standard attachment for some machine models. The usual rubber-roll assembly should be converted to the wood-rubber-roll assembly described in this publication. Typical flow path in the air-screen separator would be through the screen section, the crushing rolls, and the air column.

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